On the dynamic behavior of Vowel-to-Vowel Harmony in French: Do speakers control states or changes?

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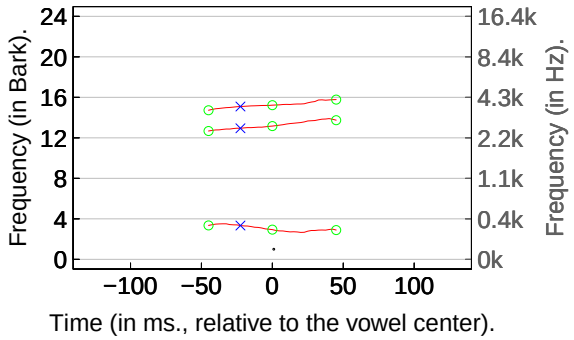
Introduction: Vowel Harmony (VH) in French, as described by (Grammont, 1933) has been investigated experimentally by Nguyen & Fagyal (2008). Acoustic analyses of the formant frequencies of vowels produced in $[...]V_1CV_2[...]$ sequences showed that french mid-vowels ([e] $\sim$ [ɛ], [o] $\sim$ [ɔ], [ø] $\sim$ [œ]) tend to exhibit a more peripheral position in the acoustic vowel space when followed by a non-low vowel compared to a mid-low or low vowel: when V_2 is low (as in /eta/), V_1 tends to be lower than when it is followed by a non-low vowel (as in /ete/). This is apparent in acoustic measurements of both F_1 and F_2 formant frequencies and the statistical analyses that were performed by the authors are overall significant. Recently, we investigated this phenomenon at 3 different positions within V_1. Indeed, though Nguyen & Fagyal (2008)'s data are in accordance with classical views on vowel harmony in French, their results were based on measurements taken from the acoustic midpoint of V_1 vowels. Our aim was to investigate the short-term evolution of this phenomenon over the time course of the harmonised vowel (cf. Fig. 1).

Figure 1: Schematic spectrogram of an actual pronounciation of V1 (3 formant tracks) in the word 'béquille' (/bekij/) produced by Speaker 3. The temporal position when F_1 reaches its maximum (identified by the crosses) precedes the vowel midpoint (mid-circles). Measurements of F_2 frequency at these positions (vowel-onset, F_1^{max}, mid-vowel) may obviously lead to alternative conclusions. Though it is obvious that this single example involves a preceding /b/ which tends to lower the F_2 frequency at this time point, our analyses are based on paired CV_1CV_2 contexts.



Experiment: In order to address this issue, an experiment was designed to investigate VH phenomena in French at different temporal positions in the supposedly harmonised vowel in order to provide data on the temporal course of formant trajectories when V_2 is either a low or a non-low vowel. Four French speakers participated in this experiment. A series of repeated measures ANOVAs was performed on each of the first three formants at 3 temporal positions within the first vowel. These analyses partly confirm Nguyen & Fagyal (2008)'s conclusions. Though there's a broad influence of V_2 on the spectral properties of V_1 at the three investigated temporal positions, not all $V_1 - V_2$ associations lead to significant effects. Specifically, there was

no significant harmonic influence for rounded vowels (V_1 = /O/, $V_2 \in$ /o, ɔ, ø, œ) and, concerning unrounded vowels (V_1 = /E/, $V_2 \in$ /i, e, ɛ, a), only when V_1 is followed by one of the more extreme vowels (namely /i/ and /a/) is the effect stable, leading to hypothesize a strong influence of the articulatory / acoustic distance between V_2 targets.

As a parallel complement to this analysis, we have started investigating the relationships between this phenomenon and temporal properties of the speech signal. Indeed, though V-to-V coarticulation has mainly been described in terms of *static targets* (speakers' articulatory configuration on V_1 would be influenced by the planned configuration for V_2), a dynamic modelling of this contextual effect may be favoured that would conceive this behavior in terms of speakers controlling trajectory slopes, *reached targets then being the consequences of these time-speed relations* (Carré, Pellegrino, & Divenyi, 2007). According to such an approach, temporal variation and evolution of V_1 formant trajectories would provide crucial insights into the modelling of this speech production behavior as these effects may ultimately depend on vowel duration.

One may then hypothesize that, in order to keep time-speed relations relatively constant within V-to-V sequences, long vowels should exhibit a reduction in vowel harmony during the initial phases of V_1 while short vowels should reflect maximal vowel harmony effects. The predicted difference between short and long vowels should vanish within the final phases. According to a static conception of this phenomenon, such a pattern may also be interpreted in terms of a variation in coarticulation distance window. However, investigating formant slopes would provide a complementary testbed for comparison of these accounts.

Results summary: After categorizing V_1s on the basis of their physical duration, we have compared the shorter 1/3rd vowels with the longer 1/3rd ones from two related points of views. Harmonic effects (low vs. non-low v_2) have been compared for v_1 formant frequencies depending on its categorized physical duration using Student's t-tests. Though all effects vanish when measuring at the beginning of v_1 (which may be attributed to the power of the test as only 1/3rd of the data are analysed), the harmonic effects occuring at the vowel-midpoint are mainly preserved for short vowels (harmonic effects appear for the 3 formants) whereas they only occur for F1 when measuring on long vowels. According to this observation, it is possible that this pattern were an expression of our prediction toward maximising harmony effects on short vowels. Nevertheless, it may also occur due to a reduction in sample power.

Discussion: Complementary analyses are being performed in order to clarify these patterns, among which investigating the difference between V_1 and V_2 formant frequencies (resp. F_1 and F_2) as this harmonic phenomenon tend to make V_1 and V_2 formant frequencies get closer to one another and normalising frequencies for speaker variations in order to compensate for individual variability. We are also currently investigating an alternate methodology in order to investigate these comparisons further as a frequentist framework based on parametric comparison for means may not be the most appropriate approach to investigating these issues. Analyses based on a Bayesian framework investigating continuous formant tracks (Davidson, 2006, SSANOVA) are being peformed that would provide a more adequate approach.

References

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